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of very small spots, like that of April 30, 1908, are surrounded by a great cyclonic structure in the hydrogen flocculi, extending over a distance equal to about one third of the Sun's diameter, while it is frequently true that large spots, with strong magnetic fields, seem to influence the form of the flocculi over a very much smaller area. Thus it can hardly be said that such evidence is favorable to the electro-magnetic explanation, particularly when it is remembered that beautiful cases of apparent lines of force or vortex structure, covering great areas, are frequently shown on *H $\alpha$*  photographs in regions where no spot is present.

The questions raised in these notes will be discussed more fully in a paper containing the quantitative results of the present investigation, which will soon be published. A single suggestion may, however, be added here. If the apparent lines of force uniting two spots of opposite polarity are of hydrodynamical origin, they suggest that one spot should be regarded as a source and the other as a sink. As EVERSHED's published results all indicate an inward flow at the  $H_{\beta}$  level, the existing data seem to be opposed in this case to the hydrodynamical explanation.

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## A REVIEW OF THE RECENT OBSERVATIONS OF *MARS*.<sup>1</sup>

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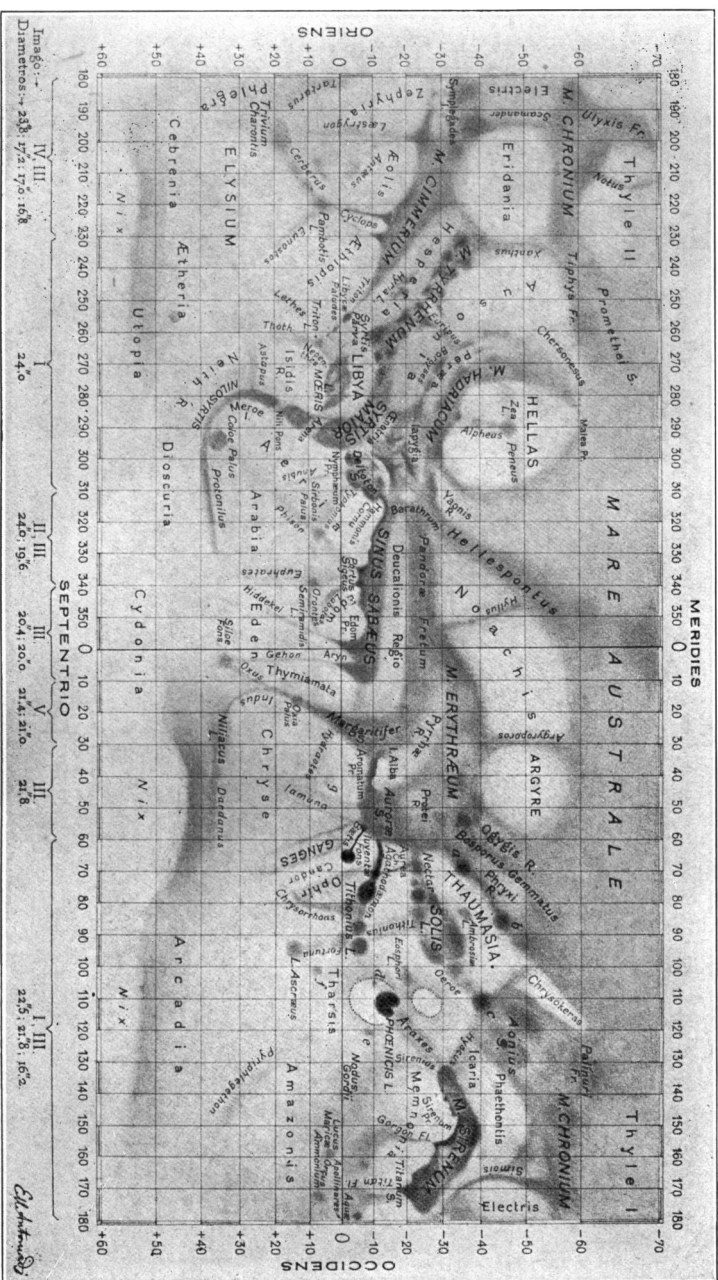
BY R. G. AITKEN.

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It is my purpose this evening to give you a short account of the recent observations of *Mars*, and of the general conclusions that I think may fairly be drawn from these observations. As a man's opinions are necessarily influenced in a greater or less degree by his experience and training, it may be well to premise that I speak from the point of view, not of the expert areographer, but of the interested student, who has familiarized himself with the literature of the subject and who has also had many opportunities during the past sixteen years to study the planet directly, under favorable observing condi-

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<sup>1</sup> This is an abstract of an address given before the Society at its annual meeting on March 26, 1910. Lantern slides of drawings and photographs of *Mars* made during the last three opposition periods were exhibited to illustrate the address.



GENERAL MAP OF THE PLANET MARS.  
From observations made at Meudon in 1909 by E. M. ANTONIAD.

tions, with refracting telescopes varying in aperture from  $3\frac{1}{2}$  inches to 36 inches.

. . . . .

We may say, then, that in recent years observations of *Mars* have had for their main object the settlement of two questions—(1) What is the nature of the surface detail, and, particularly, of that portion known as the “canals”? (2) Is it possible by direct observation to establish indisputably the fact that water vapor exists in the Martian atmosphere? In connection with the former a practical question of considerable interest has been raised,—namely, the size of telescope best adapted to the study of planetary detail.

What light have the observations during the recent opposition of the planet thrown upon these questions?

No complete account of Mr. LOWELL'S work during the past year has as yet been published, but from some short bulletins and notes from his pen it is clear that his observations have only confirmed him in the views that he has previously expressed. For example, he has recently announced the discovery of two canals—new not only in the sense that they had not previously been seen by terrestrial observers, but also new, in his opinion, to *Mars* itself. Speaking of these canals, he says: “In form they are like all the other canals—narrow, regular lines of even width throughout, running with geometric precision from definite points to another point where an oasis is located. This oasis resembles all the other oases—a small, round, dark spot. They partake, therefore, of all the peculiar features of the canal system—features which I have elsewhere shown make it impossible of natural creation,—that is, of being the result of any purely physical forces of which we have cognizance. On the other hand, the system exactly resembles what life there would evolve under the conditions we know to exist.”<sup>1</sup>

Mr. LOWELL thus gives a clear statement of one answer to our first question. In his view, the canals are the visible evidence of a vast irrigation system developed by Martian engineers to husband and distribute economically the scanty supply of water that exists upon the planet.

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<sup>1</sup> *Nature*, 82, 489, 1910.

The great majority of observers during the past opposition, however, take direct issue with Mr. LOWELL on this point; for almost without exception their testimony is that they have been unable to detect any evidence of the existence of this geometrical network of canals. Surface detail in abundance they have seen and drawn in their sketches, including many canals. But the latter are, in general, not of uniform width and shading; they are not perfectly straight; they do not follow great circle arcs. In general, too, they are not so narrow as Mr. LOWELL's canals. In a word, they have a less artificial and a more natural appearance. Thus, the well-known English observer, Mr. A. STANLEY WILLIAMS, uses the word "irregularity" to characterize the dominant impression received by him in his study of the planet's surface. There were plenty of so-called canals, "but not one of them could be described as a geometrical, narrow, straight line of uniform width. All were obviously more or less irregular or complex." M. COMAS SOLA and M. ANTONIADI, who, like Mr. WILLIAMS, are observers of recognized ability and who have, like him, studied *Mars* for years, are even more emphatic in their statements. Indeed, they do not hesitate to say that the geometrical canal system is a pure illusion.

M. R. JONCKHEERE, on the other hand, enthusiastically supports Mr. LOWELL's observations and, in fact, surpasses them. For, with a 14-inch telescope, he sees all of the older canals, verifies every one of the four hundred discovered at Flagstaff, and *adds twenty-three new ones!*

I have mentioned only a few observers and only a few typical statements of results. The time limits set me do not permit me to go into great detail. But I think it will be clear to you from what I have said that our first question is not yet conclusively answered.

It should be noted that Mr. WILLIAMS's telescope is a reflector with a  $6\frac{1}{2}$ -inch mirror; that M. COMAS SOLA employed a refractor of 15 inches aperture, while M. ANTONIADI enjoyed the privilege of using the  $33\frac{1}{2}$ -inch Meudon refractor, the largest one in Europe. Mr. LOWELL, as is well known, uses a 24-inch refractor, which, if I am not mistaken, he sometimes, or frequently, stops down to a smaller aperture. These details have a significant bearing upon the practical question

of the size of telescope best adapted to study planetary markings, for they show that up to the limit of 24 inches aperture, at least, the visibility of the geometrical canal system is not a function of the aperture of the telescope. It is quite true that these particular markings have not been seen with the great refractors of the world, and persistent efforts have been made in recent years to discredit the large telescopes on this account. So far as I am aware, observers who have had the opportunity to use these powerful instruments under reasonably good observing conditions, have never participated in these efforts. On the contrary, I think I may say that without exception they would endorse the statement made by Professor BARNARD as long ago as 1896, in which he gives it as his experience that in the study of planetary markings the large telescope is always to be preferred to the small one when the seeing is good. Also, that, with the same proviso, nothing is gained, but something lost, when the aperture is cut down by diaphragms.

As the result of his recent experience with the 33½-inch Meudon refractor, M. ANTONIADI enthusiastically confirms BARNARD's views. Professor HALE, who has been examining *Mars* both visually and photographically with the 60-inch reflecting telescope at Mount Wilson, also supports these views heartily. All three of these observers point out that while they have been unable to see a trace of the geometrical network, they have seen a great amount of detail, much of it far more delicate and fine than the "canals."

It is of course true that the almost constant disturbances in the Earth's atmosphere make it impossible to realize the full power of a large telescope on many nights when a smaller instrument can be used to advantage, and that "good seeing" is indispensable for the best work with a telescope of any aperture. It is beyond question that fine details can be seen with a small telescope under good atmospheric conditions that would be missed with a larger one when the seeing is bad. Every experienced observer is aware of this, and Mr. LOWELL and M. ANTONIADI are in entire accord in stating that good views of the surface detail on *Mars* are only to be enjoyed when the seeing is good.

The question may then be asked, Can it be due to differences in the seeing that one observer sees the geometrical net-

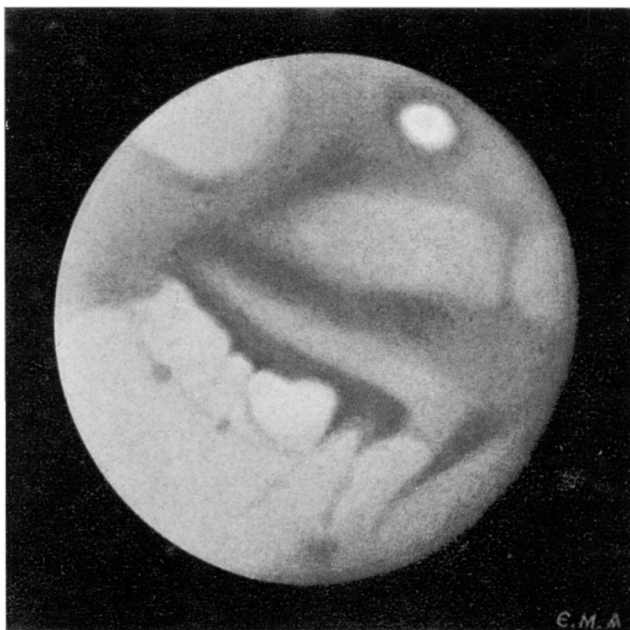
work of the canals while another does not? The records of the past year's work on *Mars* make it very difficult to believe that this is the explanation. There may be more nights with good seeing at one station than at another, but certainly there were some good nights last year at all the stations from which *Mars* was observed. M. ANTONIADI, for example, expressly states that the seeing at Meudon was bad on many nights and excellent on but few, but it was when the seeing was best that he saw the finest detail, and was at the same time most certain of the absence of the geometrical canal system. Mr. LOWELL praises the atmospheric conditions at Flagstaff in the highest terms, and he sees the canals; it is admitted by astronomers generally that the seeing at Mount Hamilton is good, and we do not see the canals. I have not, personally, had the privilege of comparing the seeing at these two sites, but I have discussed the subject with at least four astronomers—two from each observatory—who have looked through the telescopes at both places, and from all I gain the very definite impression that our standard of gauging the seeing is higher than the one in use at Flagstaff. That is, seeing that is there rated at 3 (on a scale on which 5 denotes perfect conditions) would be rated as less than 3 on the same scale here. This impression is confirmed by the recently published statement of another astronomer who has visited both the Lick and the Lowell observatories. The conclusion I draw from this fact and from M. ANTONIADI's experience is that the visibility of the geometrical canal system at Flagstaff and its non-visibility at Mount Hamilton and Meudon are not due to superior atmospheric conditions in Arizona.

For the present, then, we must be content to let the question remain open and simply state that the visual observations of the past year are as contradictory as those of previous oppositions, though the weight of evidence, on the whole, is this year more favorable to the theory that the markings on *Mars* are of natural origin.

You will recall that attempts were made as long ago certainly as 1892 to photograph *Mars*. But these early experiments were not very successful. It is only within the last few years that improvements in photographic processes have really brought the planet within the reach of the camera. Excellent



MARS, OCTOBER 14, 1909; DRAWN BY E. M. ANTONIADI.



MARS, OCTOBER 19, 1909; DRAWN BY E. M. ANTONIADI.

work in this respect, as in visual observation, has been done at the Lowell Observatory and very successful photographs have there been taken. Mr. LOWELL is on record to the effect that these photographs confirm the visual observations in showing geometrical canals. But in this, as in his visual results, he has not been able to convince all capable areographers. The slide now thrown on the screen, for example, is a drawing which records all the trustworthy detail that M. ANTONIADI could see on the photographs of *Mars* taken by Mr. LOWELL on July 11, 1907. It is obvious that this drawing does not support the geometrical theory.

During the recent opposition of the planet, photographs were made not only at Flagstaff, but at Mount Wilson and at the Yerkes Observatory, by Messrs. HALE and BARNARD, and also by MM. LA BAUME PLUVINEL and F. BALDET, who mounted a double telescope on the Pic-du-Midi in France—a station whose elevation and excellent atmospheric conditions gave promise of good results. This double telescope consisted of a reflector of one-half meter aperture and a refractor of one-fourth meter aperture carried on the same mounting. With it eighty plates showing 1,350 images of *Mars* were obtained. The observers say that these photographs show nearly all the details visible in a telescope, but of the system of geometrical canals, “we have not been able to find a trace upon our plates.”

The beautiful slides<sup>1</sup> kindly sent me by Professors BARNARD and HALE, as you see, also fail to show this system, though they exhibit much delicate detail.

Further advances in the photographic art will undoubtedly be made, and within a few years the art may reach such perfection that this troublesome “canal” question will be definitely settled by its aid. At present we can only say, as we did of the visual observations, that the weight of evidence obtained in the past opposition favors the “natural” theory.

In the time that remains I wish to present some recent evidence bearing on the question whether it is possible by direct observation to demonstrate that water vapor exists in the Martian atmosphere. It is very generally accepted that the phenomena of the polar caps and the rare “clouds” observed on the terminator of *Mars* are due to water in the form of

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<sup>1</sup> I regret that I cannot reproduce these photographs here.

vapor and in some frozen form,—hoar-frost, snow, or ice,—though other theories have been advanced. Aside from this evidence, we have at present no method of detecting the presence of water vapor on *Mars* except by means of the spectro-scope.<sup>1</sup>

This is not the appropriate place, even if time permitted, to give an account of the many efforts that have been made to determine whether or not water-vapor absorption lines are present in the spectrum of *Mars*. The problem is by no means an easy one to work out, for the sunlight reflected to us by *Mars* must pass through our own atmosphere as well as his, and our atmosphere always contains more or less water vapor. The spectrum also contains a vast number of lines of purely solar origin intermingled with the atmospheric absorption lines. Great skill and care are needed to avoid the errors that may be introduced into the result by these confusing elements.

It is necessary to select water-vapor lines in those parts of the spectrum where the solar lines are comparatively few and relatively feeble, and to eliminate the absorption due to terrestrial water vapor by comparing spectra of *Mars* with spectra of the Moon, taken as nearly as possible at the same time and under the same conditions as to the instrument and as to the position of the bodies in the sky. The Moon is known to have no water vapor on its surface, hence the water-vapor absorption in its spectrum is due to our own atmosphere. Comparing the Moon's spectrum with that of *Mars*, we note whether or not the water-vapor lines in the latter are of equal or of greater intensity. If they are only of equal intensity, the investigation gives a negative result—there is no evidence of the existence of water vapor in addition to that known to be present in our own atmosphere.

Dr. CAMPBELL has recently published <sup>2</sup> an exhaustive critical review of all of the spectroscopic observations of *Mars* up to the opposition just past, and has shown that they have not given a conclusive answer to our question. Even the observations by Mr. SLIPHER at Flagstaff in 1908, from which Mr. VERY finds definite evidence of the existence of water vapor

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<sup>1</sup> A polariscopic method of detecting the presence of water vapor was suggested by Mr. N. H. PICKERING some years ago if I am not mistaken. I have, however, been unable to find the account of it.

<sup>2</sup> *Lick Observatory Bulletin*, No. 169.

in the atmosphere of *Mars*,<sup>1</sup> cannot be accepted without reservation, owing to the possibility that the intensification of the lines in the spectrum of *Mars* may be due to changes in the vapor content of our own atmosphere in the intervals of several hours that occurred between Mr. SLIPHER's photographs of the planet and those of the Moon.

You are aware of the fact that Dr. CAMPBELL has himself been one of the investigators of this question; that he obtained a negative result from his observations at Mount Hamilton in 1894 and that he has recently repeated these observations on the same general plan from a station on the summit of Mount Whitney, 14,501 feet above sea-level. This station was chosen because its elevation raised it above the major part of the water vapor in our own atmosphere and because at the time when *Mars* and the Moon could be observed<sup>2</sup> in quick succession at about the same altitude (and hence through the same layer of our own air) the air above the mountain was likely to be relatively dry. The results may best be stated in the observer's own words: "The conclusion drawn from this investigation, in view of the extreme faintness and apparent equality of the *a* bands [the water-vapor absorption lines in the part of the spectrum photographed] in the Martian and lunar spectra, as observed through a minimum of water vapor, is that the quantity of any water vapor existing in the equatorial atmosphere of *Mars* at the time these observations were made was too slight to be detected by present spectrographic methods."

Dr. CAMPBELL has kindly authorized me to give you a brief account of a still more recent investigation of this question, the results of which have not yet been published. You are aware of the fact that the spectroscope enables us to measure the radial velocities of light-giving bodies by means of the slight displacements of the spectral lines due to this motion. Conversely, then, if such a body is known to be in motion relatively to the Earth, we can determine which lines in its photographed spectrum are due to light from the body and which ones are due to absorption by our own atmosphere, by measuring the relative displacements of the lines. To do this

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<sup>1</sup> *Lowell Observatory Bulletin*, 1, 207, 221, 1909.

<sup>2</sup> The actual dates of observation were September 1 and 2, 1909.

with any accuracy requires a spectrograph of high dispersion, one, that is, which separates the various lines in the spectrum sufficiently to admit of accurate measures of their position. The spectrographs hitherto employed in the study of the Martian spectrum have had too low a dispersion to permit this principle to be used.

In the investigation now to be described a grating spectrograph was used, constructed on plans prepared by Dr. CAMPBELL, in conjunction with the 36-inch refractor. Its dispersion for what is known as the D region of the spectrum, when the second-order grating spectrum is used, is equal to that of the three-prism Mills spectrograph for the blue region of the spectrum.

With this powerful instrument Dr. ALBRECHT photographed the spectrum of *Mars* in January and February of the present year at a time when it was known, from the orbital motions of the two bodies, that the planet was receding from the Earth with a velocity of about 19 kilometers per second. On measuring the plates he found that the water-vapor and oxygen lines in this part of the spectrum showed a displacement with respect to the purely solar lines that corresponded to a relative velocity very closely equaling that of *Mars* with respect to the Earth. In other words, by their displacement relatively to the lines known to be of solar origin, the water-vapor and oxygen lines proclaimed their terrestrial origin. Further, when the micrometer was set to the positions the corresponding lines should occupy if caused by absorption in the Martian atmosphere, no trace of any lines could be seen.

In estimating the weight of this last statement we must remember, as Dr. CAMPBELL reminds us in his conclusions on the Mount Whitney observations, "that the rays as photographed had passed from the Sun through the planet's atmosphere, for the most part down to its surface, and out again to us, thus traversing the Martian atmosphere twice and multiplying any absorptive effect approximately by two."

I conclude, therefore, that up to the present time it has been impossible to demonstrate by any spectrographic method that water vapor exists in the atmosphere of *Mars*.

This does not prove its non-existence, be it noted. It only proves that its amount, if it exists, must be very small—much

less, probably, above unit area on *Mars* than in our atmosphere about the same area of Mount Whitney.

It is difficult to understand how so small an amount of water can keep a geometrical canal system on *Mars* in active operation.

March, 1910.

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## ON THE SPECTRUM OF *MARS* AS PHOTOGRAPHED WITH HIGH DISPERSION.

BY W. W. CAMPBELL AND SEBASTIAN ALBRECHT.

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Let us recall that the solar spectrum, as viewed by terrestrial observers, is composite. Photospheric light, in passing out through the gases and vapors of the Sun's atmosphere, is selectively absorbed, with the result that many thousands of lines are introduced into the spectrum. These rays pass down through the Earth's atmosphere to the observer, and the absorption by water vapor and oxygen in the terrestrial atmosphere introduces many hundreds of additional lines, at definite points in the yellow, orange, and red regions. The observed spectrum of the Sun is in reality the spectrum of the Sun plus the spectrum of the Earth. The spectrum of the Moon, so far as our present problem is concerned, is simply this Sun-Earth spectrum.

The light from *Mars* is photospheric light, which passes out through the Sun's atmosphere, thence down through the atmosphere of *Mars* to the planet's crust, where a certain proportion is reflected out through the Martian atmosphere, and thence down through the Earth's atmosphere to the observer. The so-called spectrum of *Mars* is in reality the Sun's spectrum plus *Mars's* spectrum plus the Earth's spectrum.<sup>1</sup> Any water vapor and oxygen in the Martian atmosphere should introduce the same absorption lines which are introduced by the Earth's atmosphere in the Sun-Earth spectrum.

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<sup>1</sup> A little of the light would be reflected from the atmospheric strata of various heights without passing down to the planet's surface. It should also be noted that the rays do not pass normally through the planet's atmosphere, but have angles of incidence and reflexion with the strata equal on the average, in the present investigation, to about 20°.